# Monitoring and Modeling to track changes in terrestrial productivity

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**NASA Ames Research Center**
**Moffett Field, CA**

**An Inter-Agency Workshop on Coordinating Approaches for Utilizing Remote Sensing-Earth Observation (RS/EO) Data to Monitor and Report Landscape Dynamics in and Around Protected Areas**

USGS Center for Coastal and Watershed Studies
St. Petersburg, Florida, March 1-3, 2005

# NPP is the balance between photosynthesis and respiration by plants

**A substantial incentive to understand trends and variability in terrestrial Net Primary Production, because NPP:**

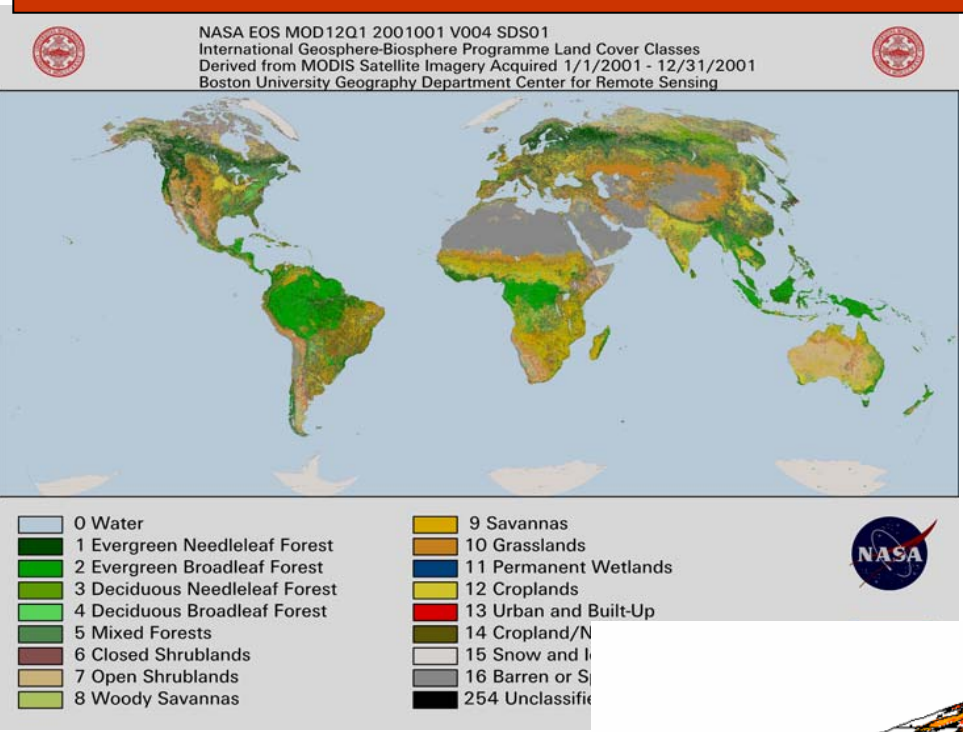
image credit: fao

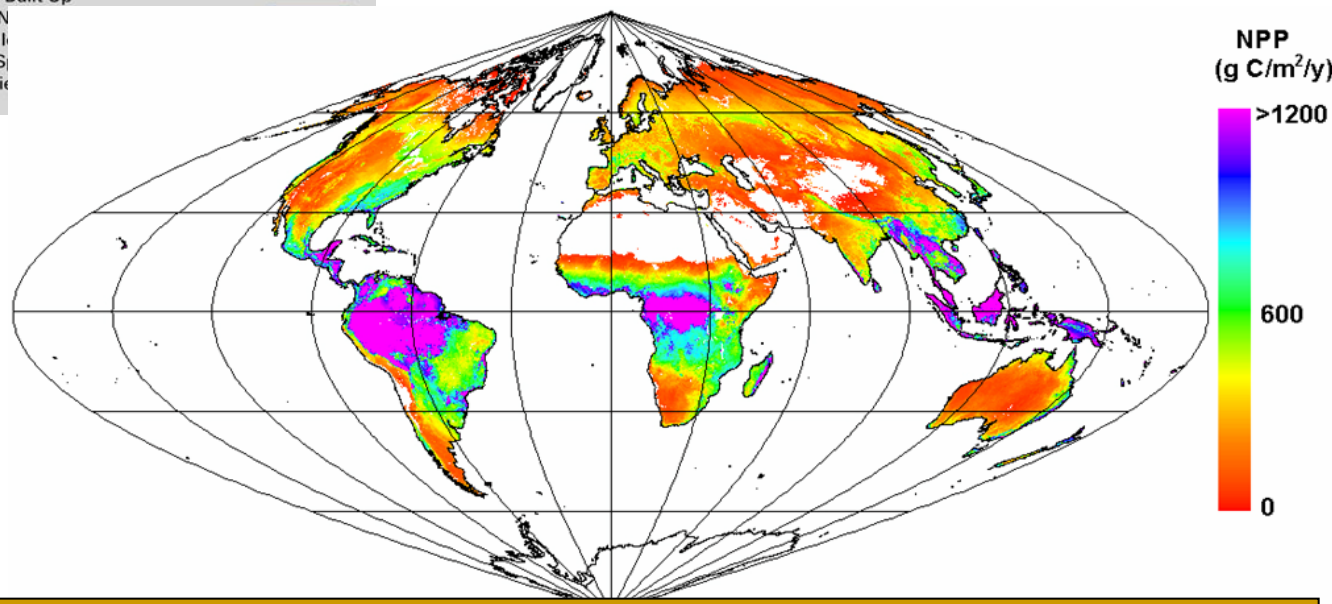
- **is the foundation of food, fiber and fuel for human consumption**

- **determines seasonal and interannual variations in atmospheric $CO_2$**

- **integrates climatic, ecological, geochemical and human influences on the biosphere**

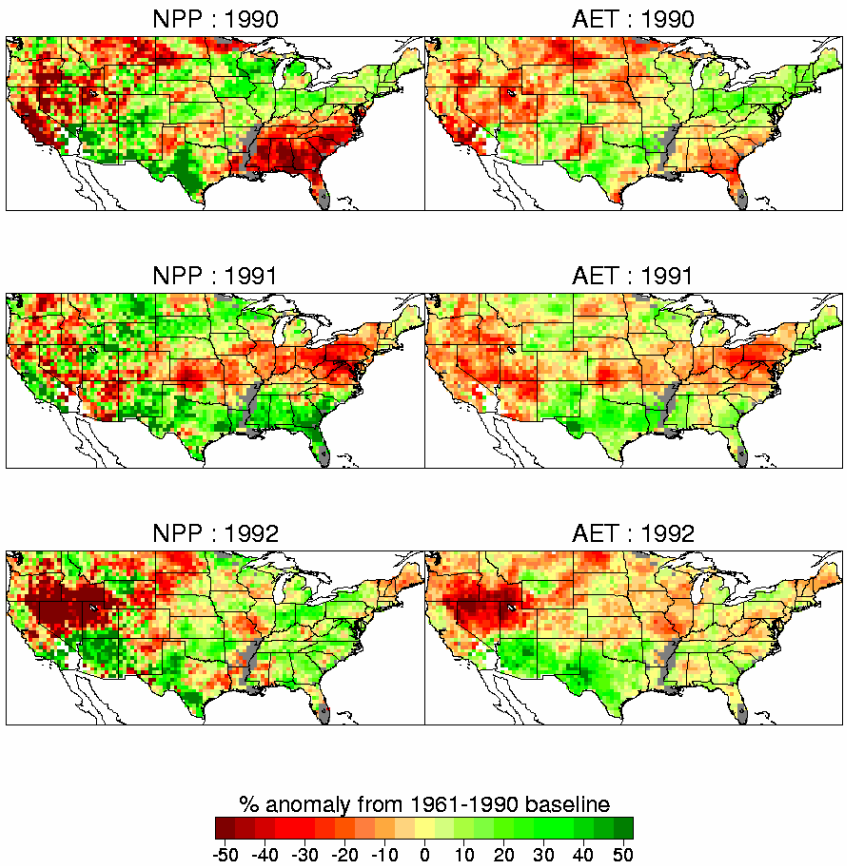
# Long-term climate + geology produce distinct patterns of vegetation and NPP



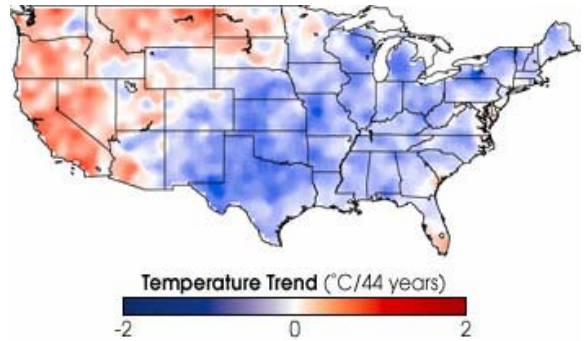



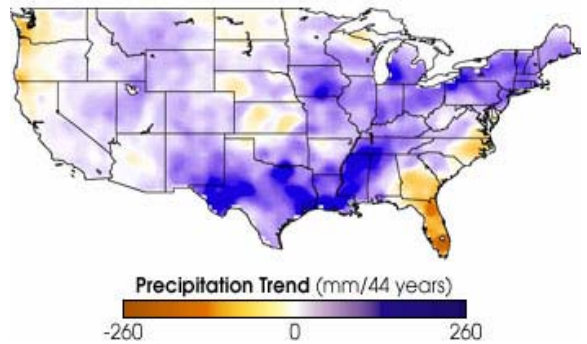
# Climate and NPP

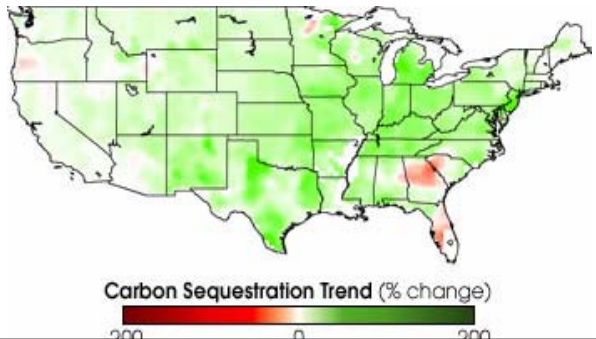
## Interannual Variability of Ecosystem Process Anomalies




## Decadal Changes (1950-1993)

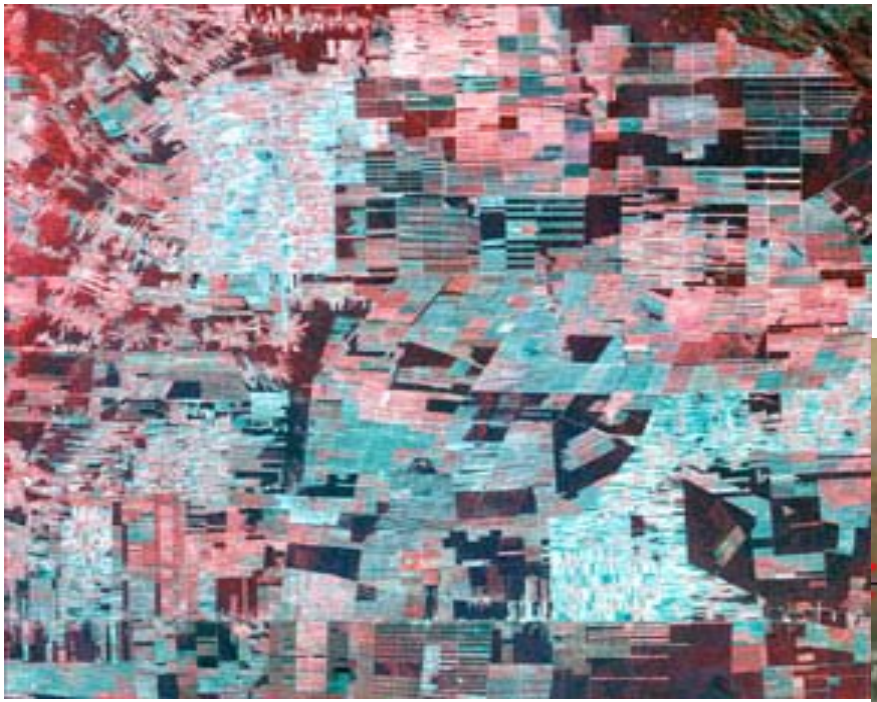


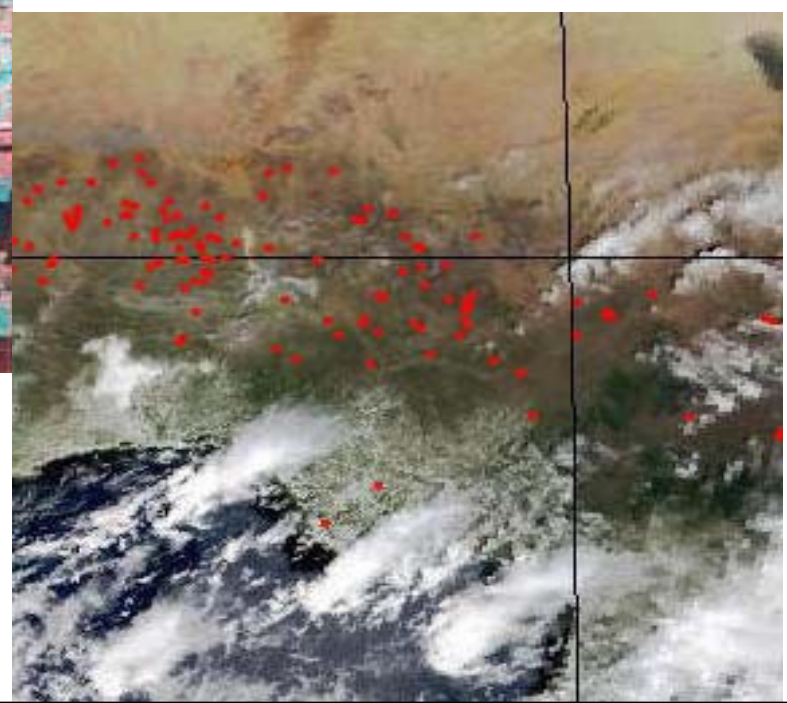




Nemani et al., Geophysical Research Letters, 2002

# Changes in land cover and NPP





# http://www-eosdis.ornl.gov/NPP/npp_home.html

Home | Project Info. | Data Holdings | Search Options | Information | Services

DAAC for biogeochemical dynamics
DISTRIBUTED ACTIVE ARCHIVE CENTER Oak Ridge National Laboratory

Policies ▶
Resources ▶
Technical/Access ▶
For Data Providers

## NPP Database

### Overview of the NPP Project

The ORNL DAAC Net Primary Production (NPP) Database contains field measurements of biomass and estimated NPP for terrestrial sites worldwide, compiled from published literature and other extant data sources. It includes intensively studied and well-documented field study sites, together with more extensive collections of worldwide data. Compilation of these data was sponsored by the Terrestrial Ecology Program of NASA's Office of Earth Science.

### NPP Related Resources

Continue your exploration of the NPP Project using the following on-line resources:

- NPP Data Set Documents
- NPP Bibliography
- NPP Map Server
- NPP Photo Gallery
- MODIS ASCII Subsets

### Get NPP Data

Find and order data sets:

- See list of data sets
- Browse by attributes

Download data sets directly:

- FTP site

Search for related data:

- Mercury

### In-Depth

The NPP Database contains data for 61 intensive study sites. The majority of these sites are grasslands, the remainder being located in tropical forest, boreal forest, and tundra. Some combination of above-ground annual peak live biomass data and/or seasonal biomass dynamics data are available for all sites. Many sites also have data on below-ground biomass and/or turnover. A number of previously compiled multi-site, multi-biome data sets of georeferenced NPP estimates are also provided. More ....

### What's New at the DAAC?

More Data for Southern Africa Details...

Southern African Data Released Details...

VEMAP-2 Model Results Available Details...

Past announcements...

### Related Information

Web links to related information at:

- LTER ANPP Database
- MODIS NPP Products
- GEO Success: NPP

# npp evaluation from satellite data

**Step 1**: convert absorbed radiation to optimal gross production

**Step 2**: downgrade by climate limiting factors to obtain gpp

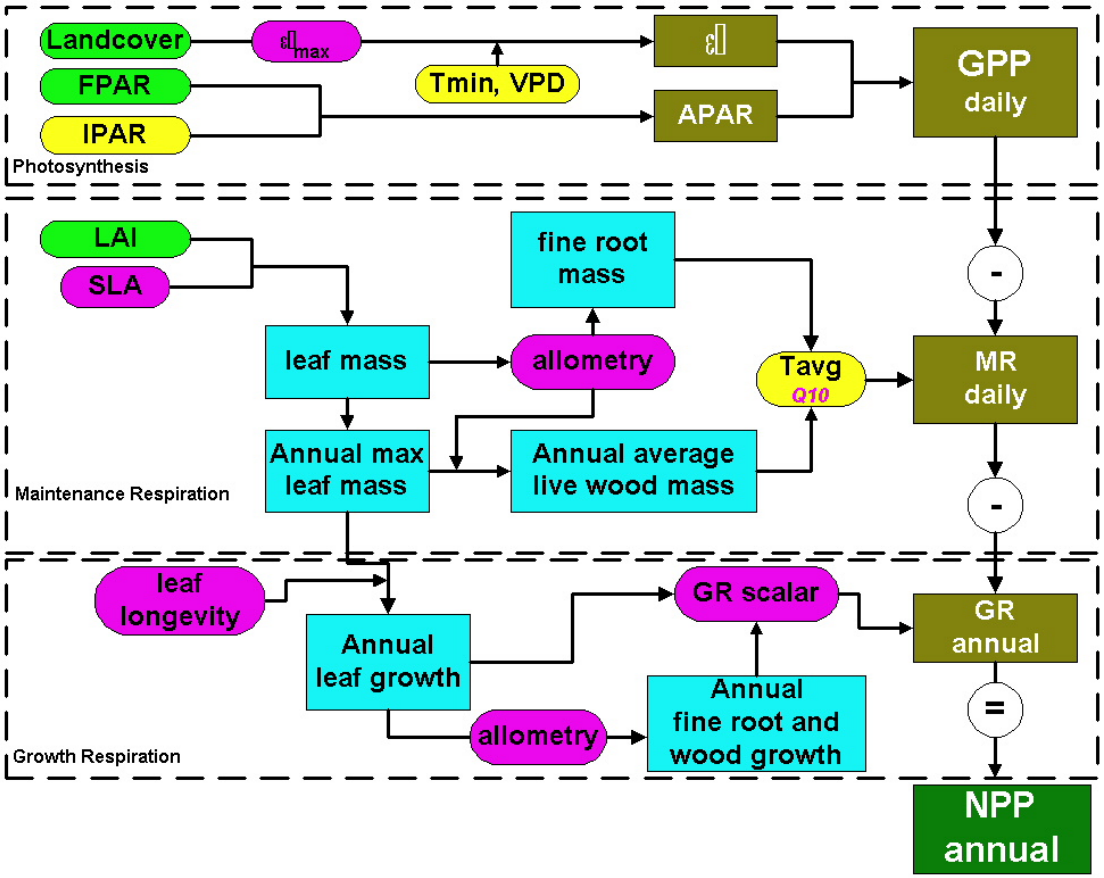
**Step 3**: subtract respiration to obtain npp

## Components of the NPP algorithm

**satellite-derived vegetation properties**: Land cover, Leaf Area Index (LAI) and fraction of absorbed photosynthetically active radiation (FPAR)

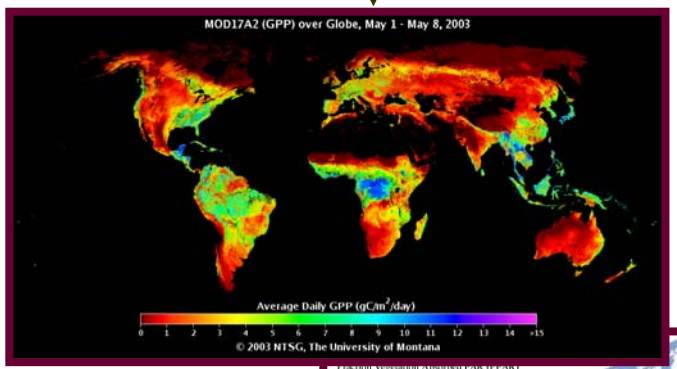
**daily climate data**: incident radiation (IPAR), minimum and average air temperatures and humidity

**efficiencies**: a biome specific parameterization to convert absorbed PAR to NPP

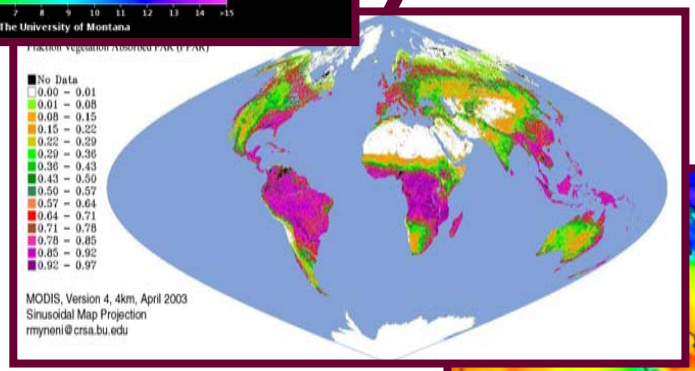


# GPP = Absorbed light X Conversion Efficiency

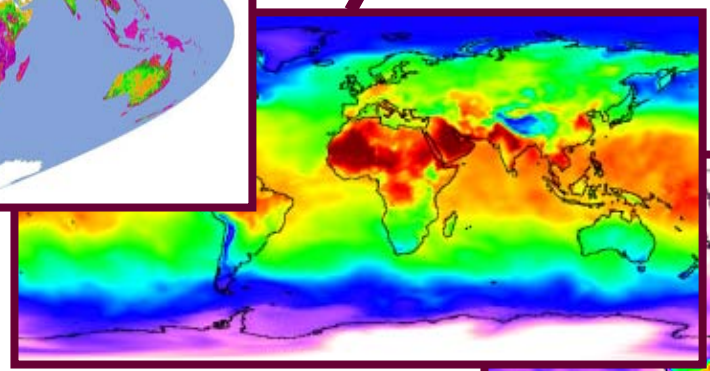
## GPP = f (PAR) x $\varepsilon$



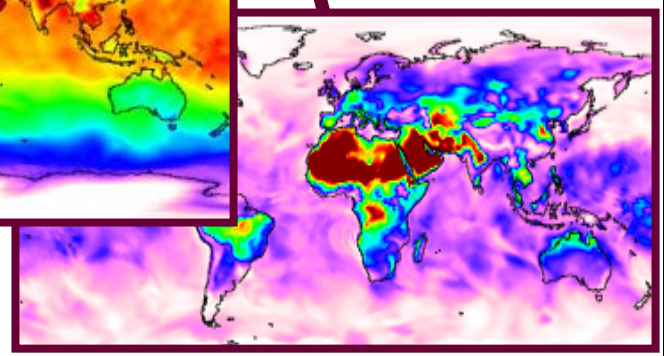

*GPP*




**fPAR, PAR**

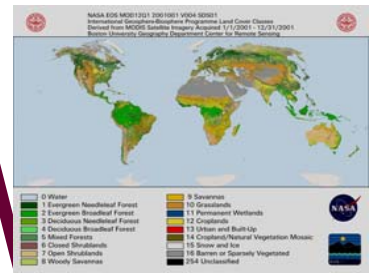


**Temperature**



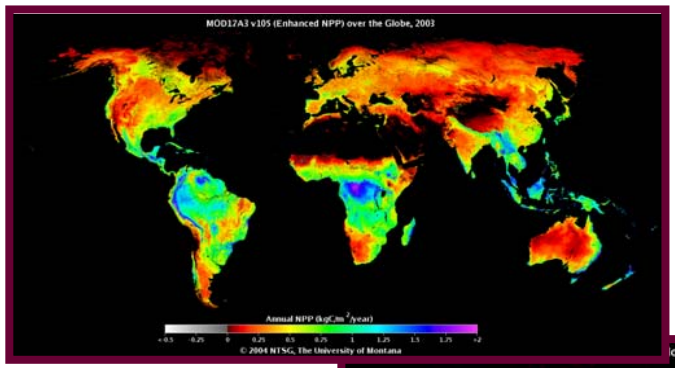
**VPD**

**Biome Properties Look-Up Table ($\varepsilon_{max}$)**

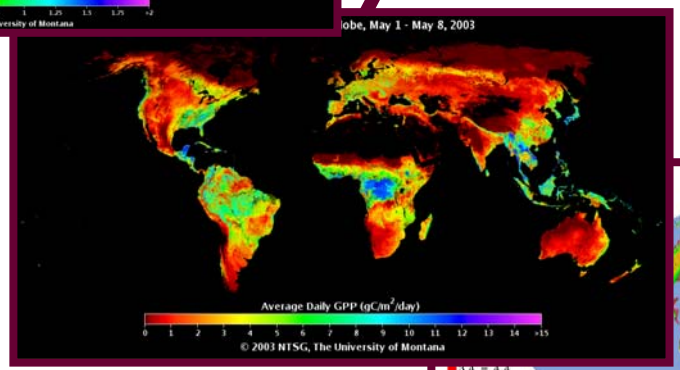


NPP = Annual GPP - Autotrophic Respiration

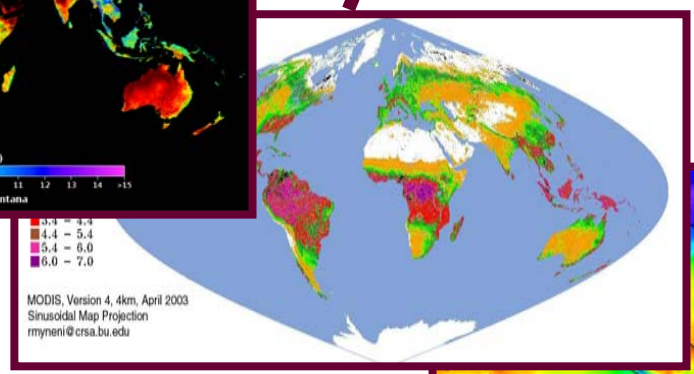
$$NPP = \sum GPP - (R_m + R_g)$$



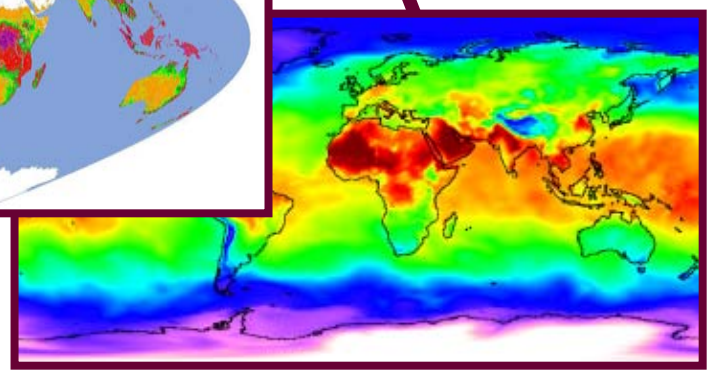

*NPP*




GPP



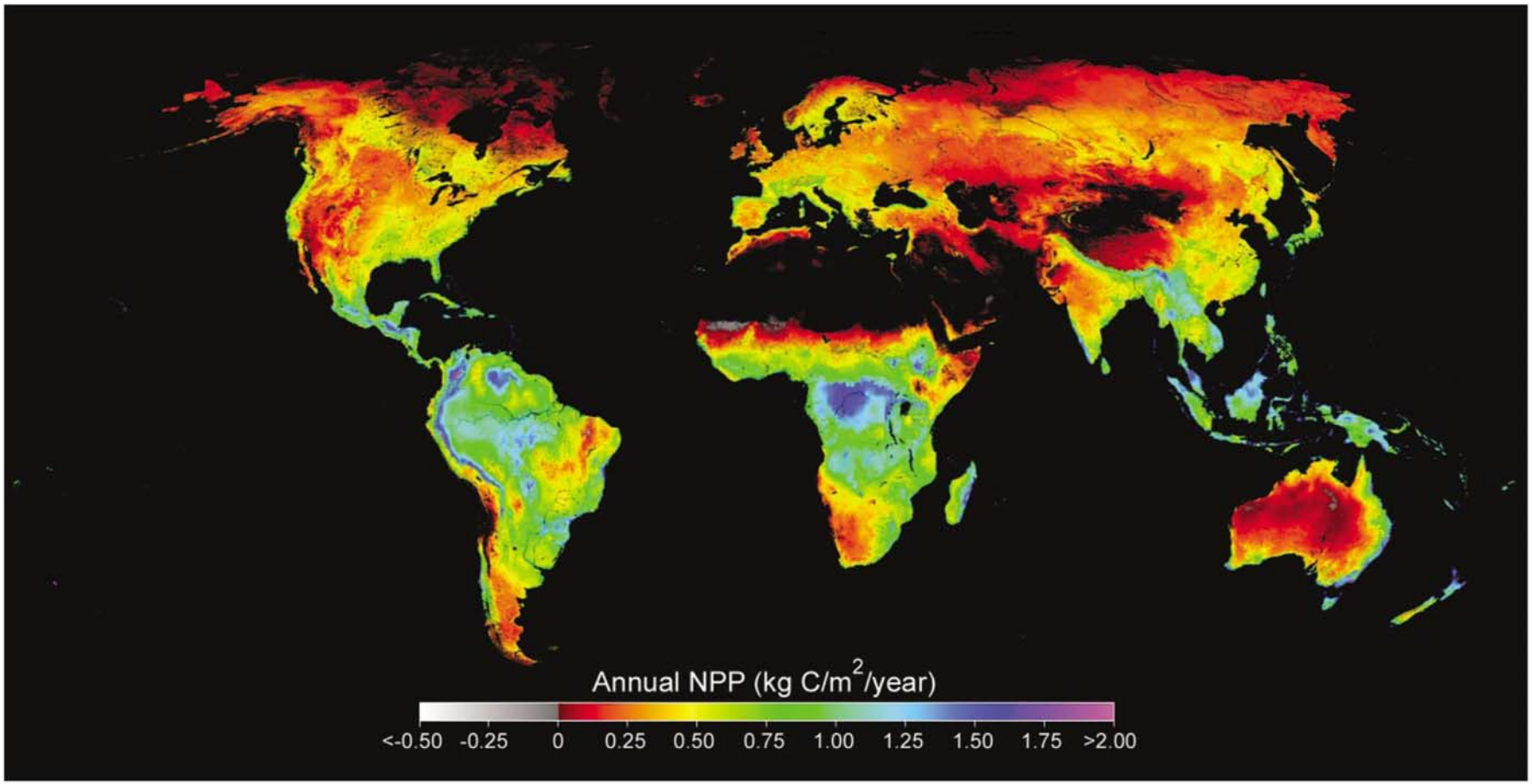

LAI



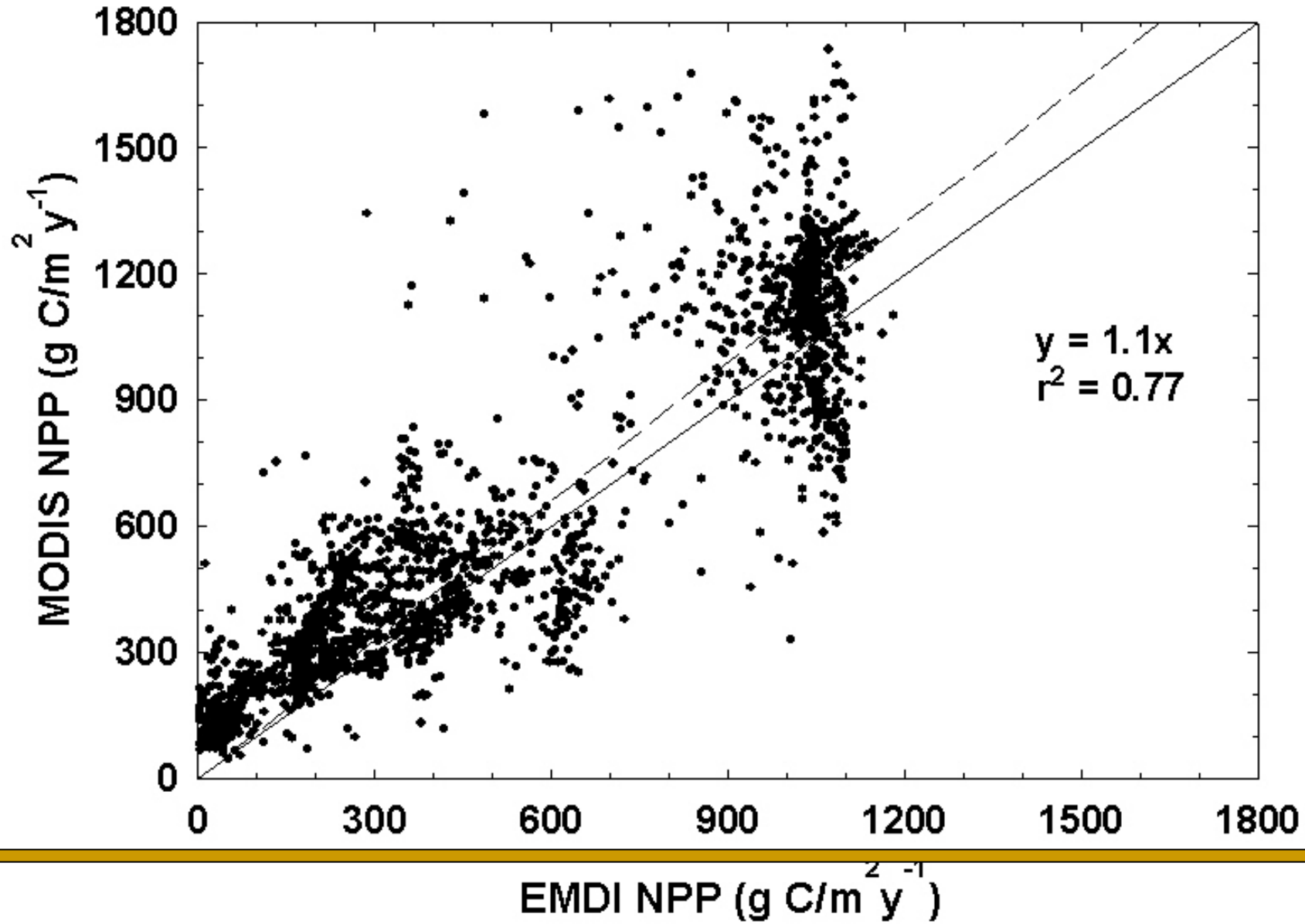
Temperature

Biome Properties Look-Up Table

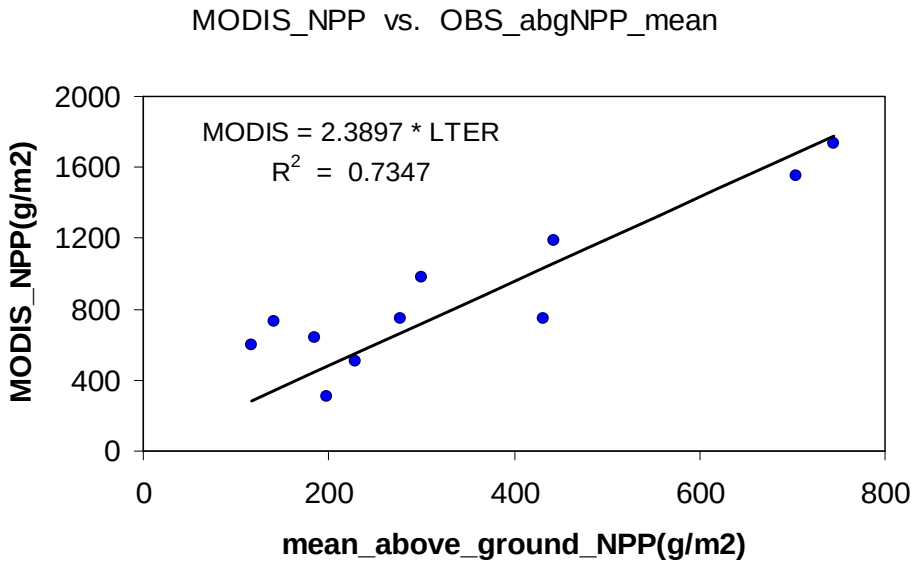
# MODIS-derived Global Net Primary Production for 2001
# 1km

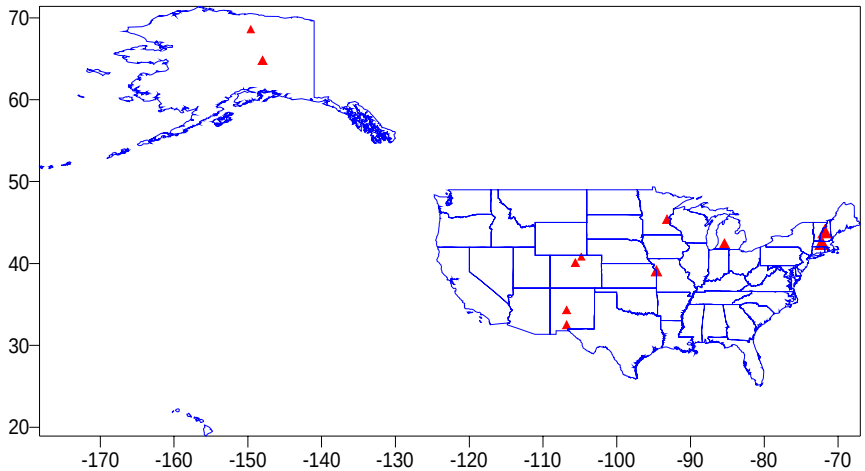


# Validation of Annual NPP



# MODIS NPP vs. LTER NPP



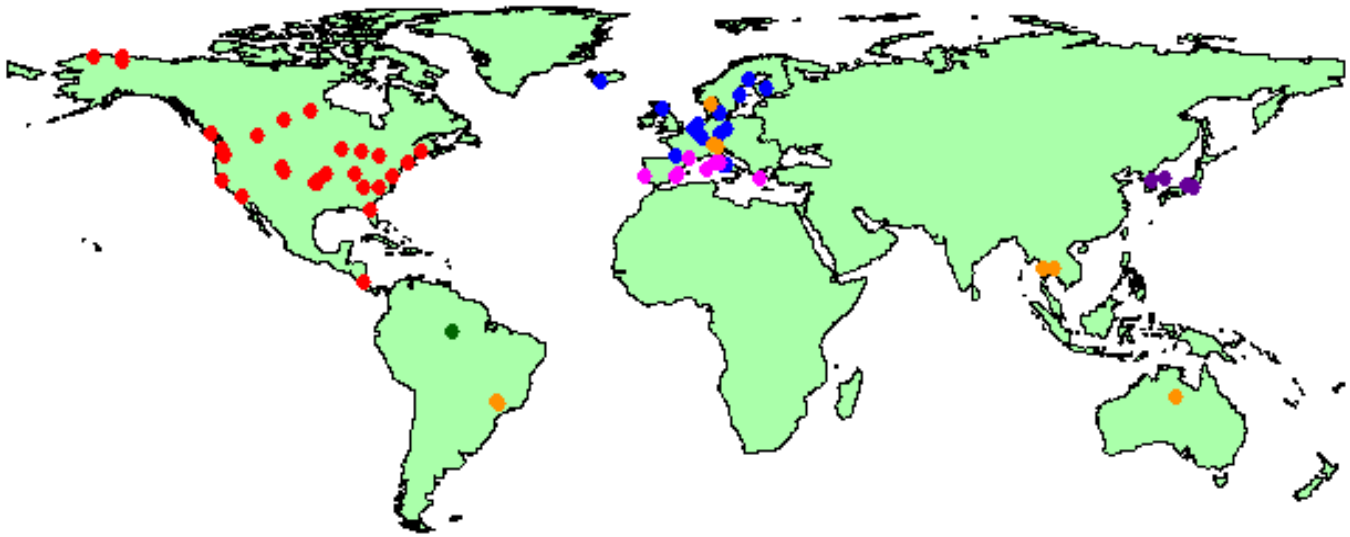




*MODIS 2001 NPP vs. long-term (mean=12years) observed above-ground NPP*

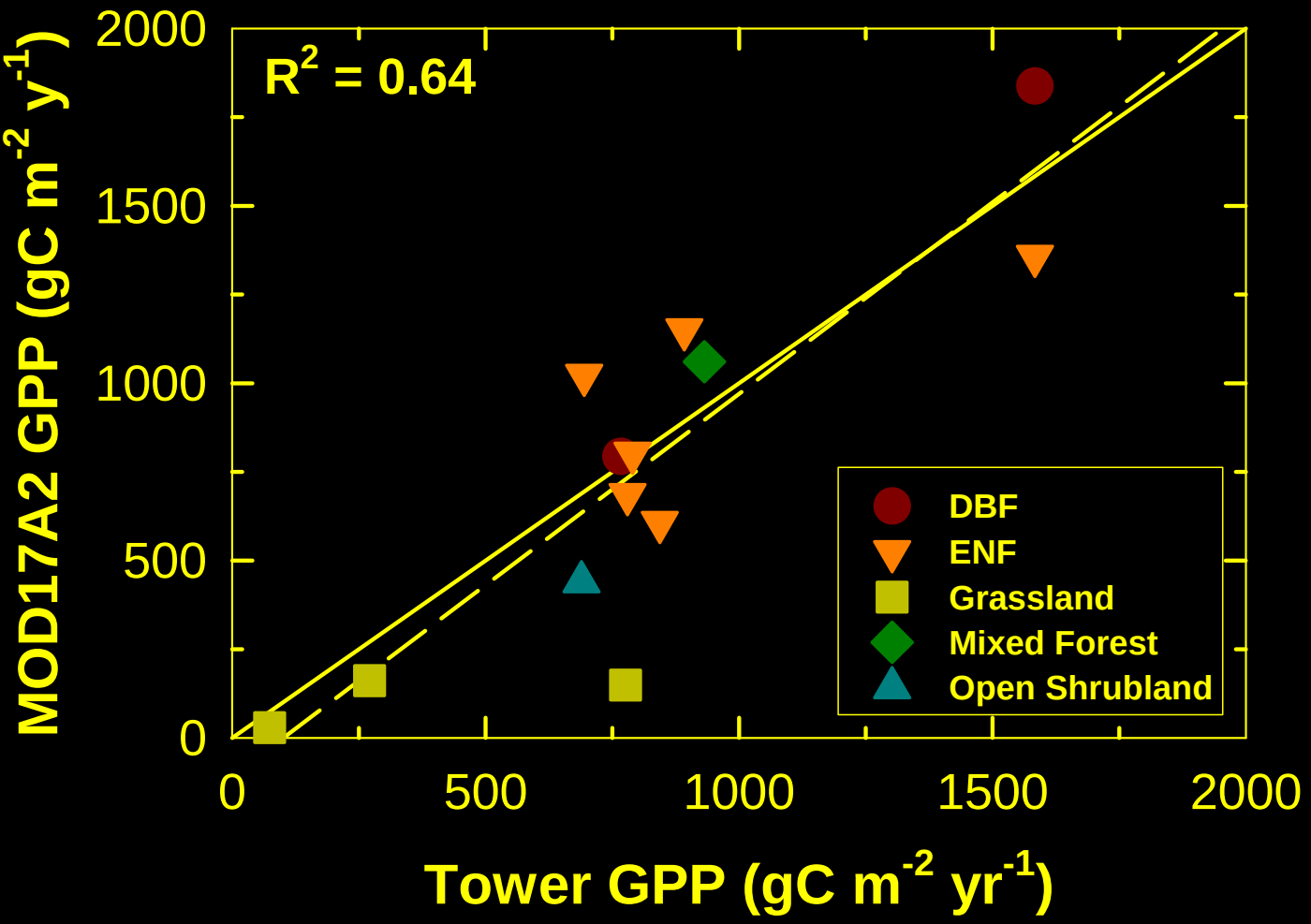
# VALIDATION OF MODIS PSN/NPP USING FLUX TOWERS

## FLUXNET Sites

AmeriFlux(•), EUROFLUX(•), Medeflu(•),
JapanNet(•), LBA(•), others(•)



# GPP from MOD17A2 Algorithm
# Using Actual Tower Data As Input Meteorology



# Uncertainties in the MOD17 (GPP/NPP) Algorithm

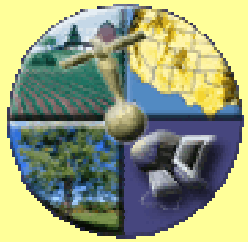
1. *Meteorological*
   DAO IPAR, Temperature, VPD

2. ***Radiometric***
   MODIS FPAR and LAI

3. ***Ecological***
   MOD17 representation of plant physiology (BPLUT)
   Accurate mapping of landcover type

NASA / NGA SRTM Elevation

NASA MODIS Products



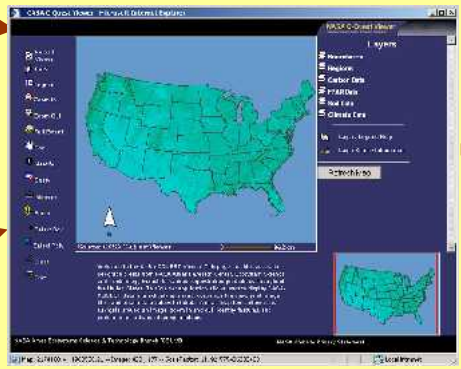
Leaf Biomass

Cropland NPP

VEMAP & Daymet (UMT) Climate data

# CASA CQUEST – A Decision Support System for Carbon Accounting

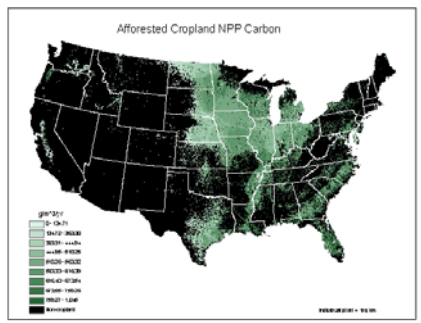
*Inputs include continental-scale land cover, NDVI, FPAR, elevation, soils, and climate data …*



**User Defined Profile**
**Region of Interest**
**Time Frame**
**Biophysical**
**Management**
**Climate Scenario**

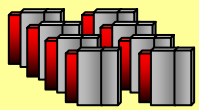
*Output: landscape-to continental scale predictive maps of above and below ground distributions of sequestered carbon for different climate scenarios*

**Carbon Sequestration Predication**



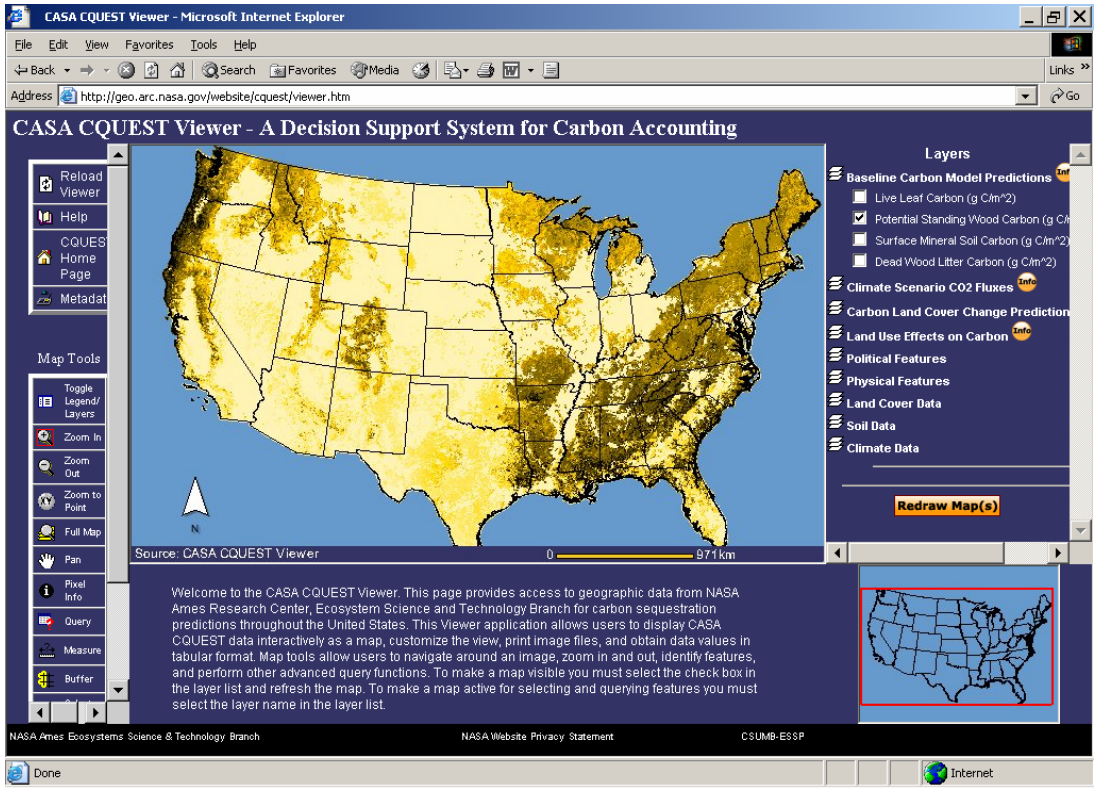

**Cropland Afforestation Prediction**

**USFS Forest Inventory and Analysis Data**



***Multi-scale Validation Information***

# CASA-CQUEST Viewer:
# A Decision Support Tool for Carbon Management

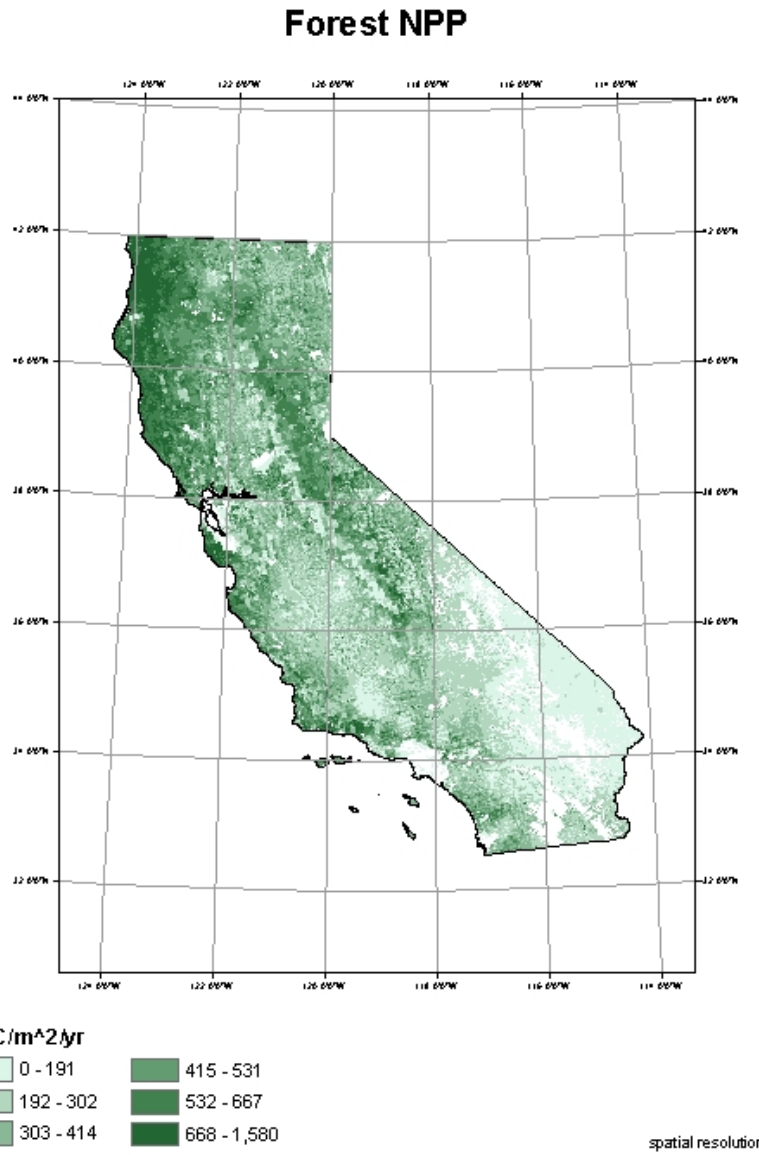



**The development of the CASA-CQUEST Decision Support Tools (DST) relies on "baseline" outputs and $CO_2$ flux predictions from the EOS-driven NASA-CASA model (Potter et al., 2003). CQUEST is an internet-based query and modeling application that allows users to display, manipulate, and save ecosystem model estimates of carbon sinks and $CO_2$ fluxes in agricultural and forest ecosystems for locations anywhere in the United States freely from a web browser. Users are able to customize the map views, navigate, overlay multiple data layers, print images, and obtain data values from any carbon map data layers in tabular format.** http://geo.arc.nasa.gov/website/cquestwebsite/

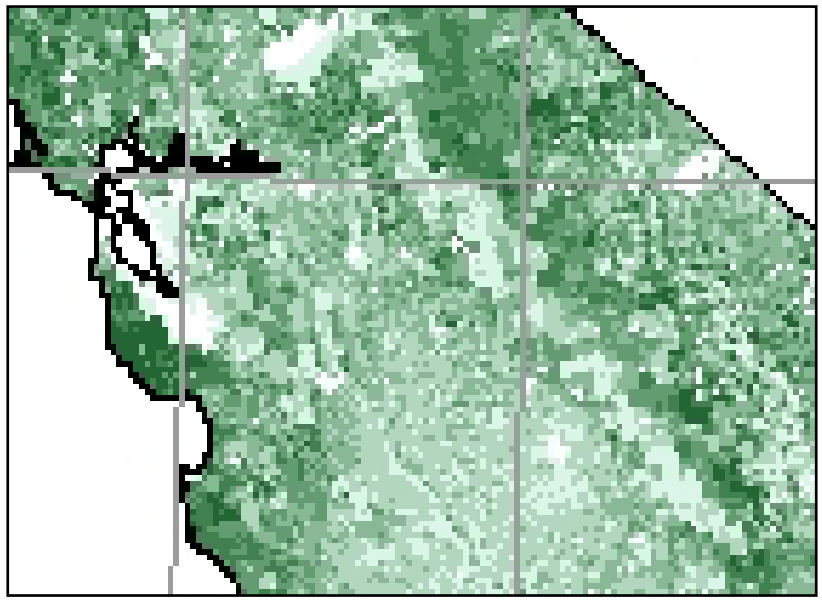
**Investigators: Christopher Potter and Matthew Fladeland (NASA ARC); Steven Klooster, Vanessa Genovese, and Marc Kramer (California State University); Supported by NASA Office of Earth Science Applications Division**

**Reference: Potter, C., S. Klooster, P. Tan, M. Steinbach, V. Kumar, V. Genovese, 2003. Variability in terrestrial carbon sinks over two decades: Part 1 – North America. *Earth Interactions*, Vol. 7, Paper 12.**

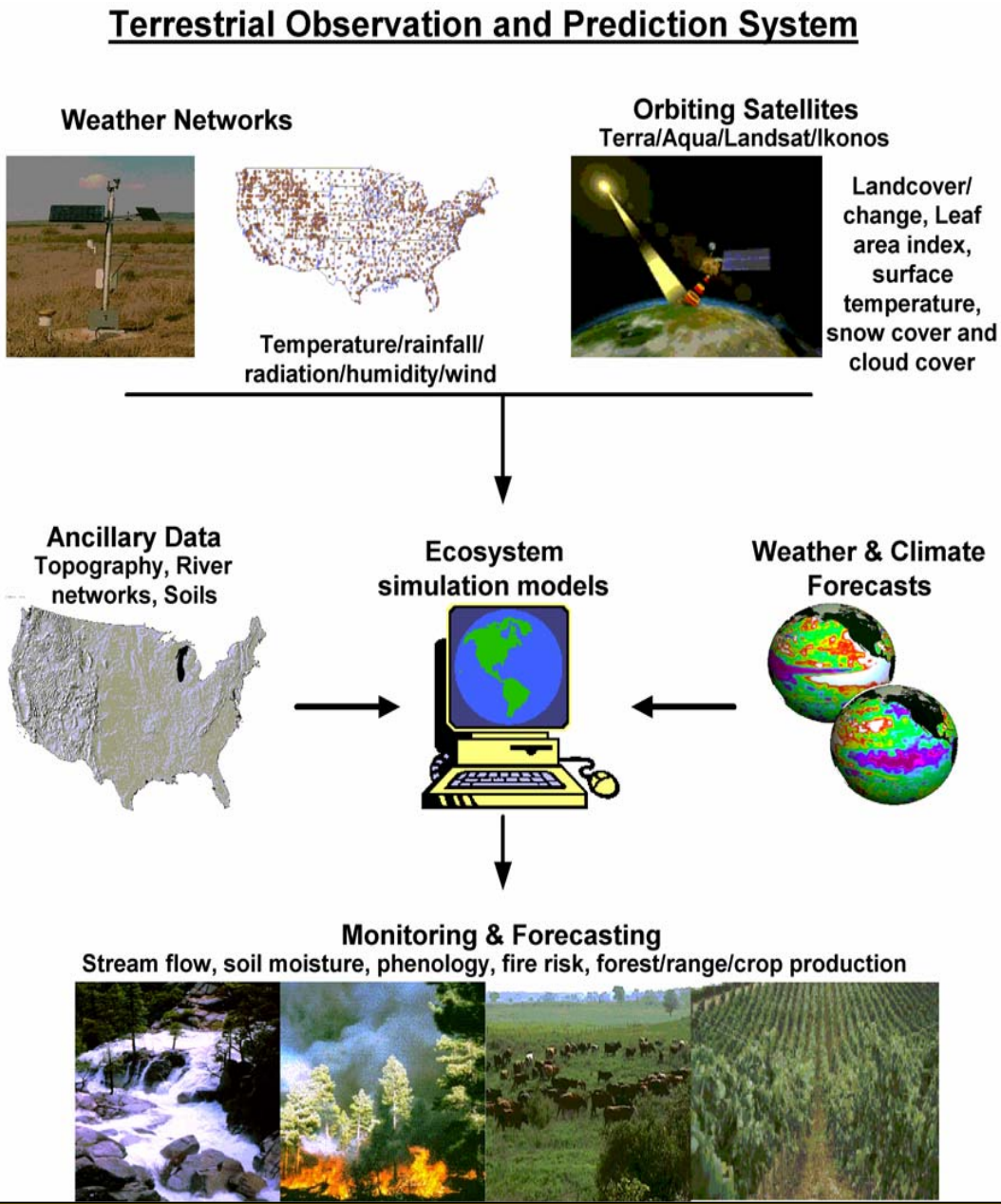
# CASA Model Prediction of Net Primary Production
## (GIS inputs include MODIS FPAR, climate, soils, elevation)




## Central CA Yosemite NP



# Multi-sensor/Multi-scale Modeling Framework

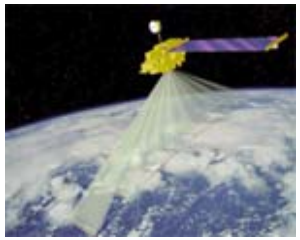



Nemani et al., 2003, EOM

White & Nemani, 2004, CJRS

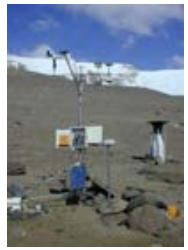
# Terrestrial Observation and Prediction System

## NASA Satellites



~1.5 TB/day

## Climate/Weather



## Ancillary Data

**Topography, River Networks, Soils, Biodiversity . . .**

10-100 MB/day

## EOSDIS

**250+ products, > 2 Petabytes**

.1-10 TB

## Ecocast Architecture

### IMAGEbot Planner

**Optimizes data processing plans and retrieves appropriate data for analyses**

### Causal Discovery

**Autonomous analysis of data for discovery of novel causal models; integrated with TOPS for model validation**

### TOPS

**Biospheric models for ecological nowcasting / forecasting from data**

**Data Overload:**

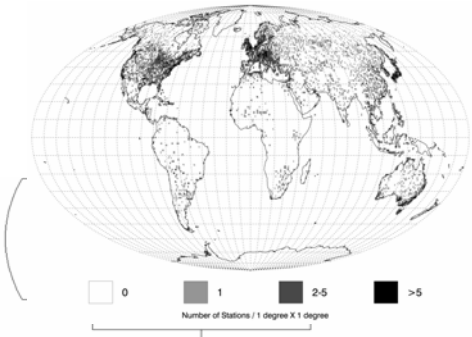
**1-100 TB**

**Massive data sets, multiple products, heterogeneous data types**

**Knowledge:**

**100K to 10 MB**

**Daily nowcast and forecast maps, integrated datasets, images, causal models**




**Data Retrieval**

Data Retrieval and Processing

Scheduler

Unattended

SQL Database

**Storage**

Modular

Observations (X,Y,Z,R)

Prediction Points (X0,Y0,Z0)

Interpolation Logic

Prediction (R0)

Crossvalidation Statistics

Interpolation Logic

Prediction Control

Ancillary Inputs

**Interpolation**

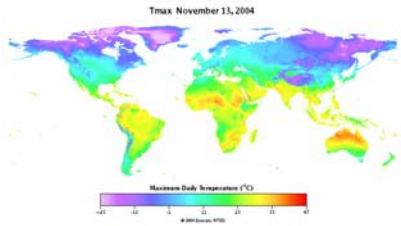
Any user Defined grid

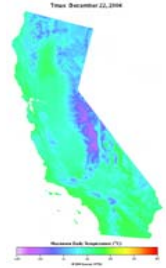
Output Handling

Predictions

**Output**

Tmax / Tmin
VPD, precipitation
Solar radiation
Daylength





Jolly, nemani and Running. 2004. Envi. Modeling and Software

# Improved estimates of GPP/NPP for local to regional applications

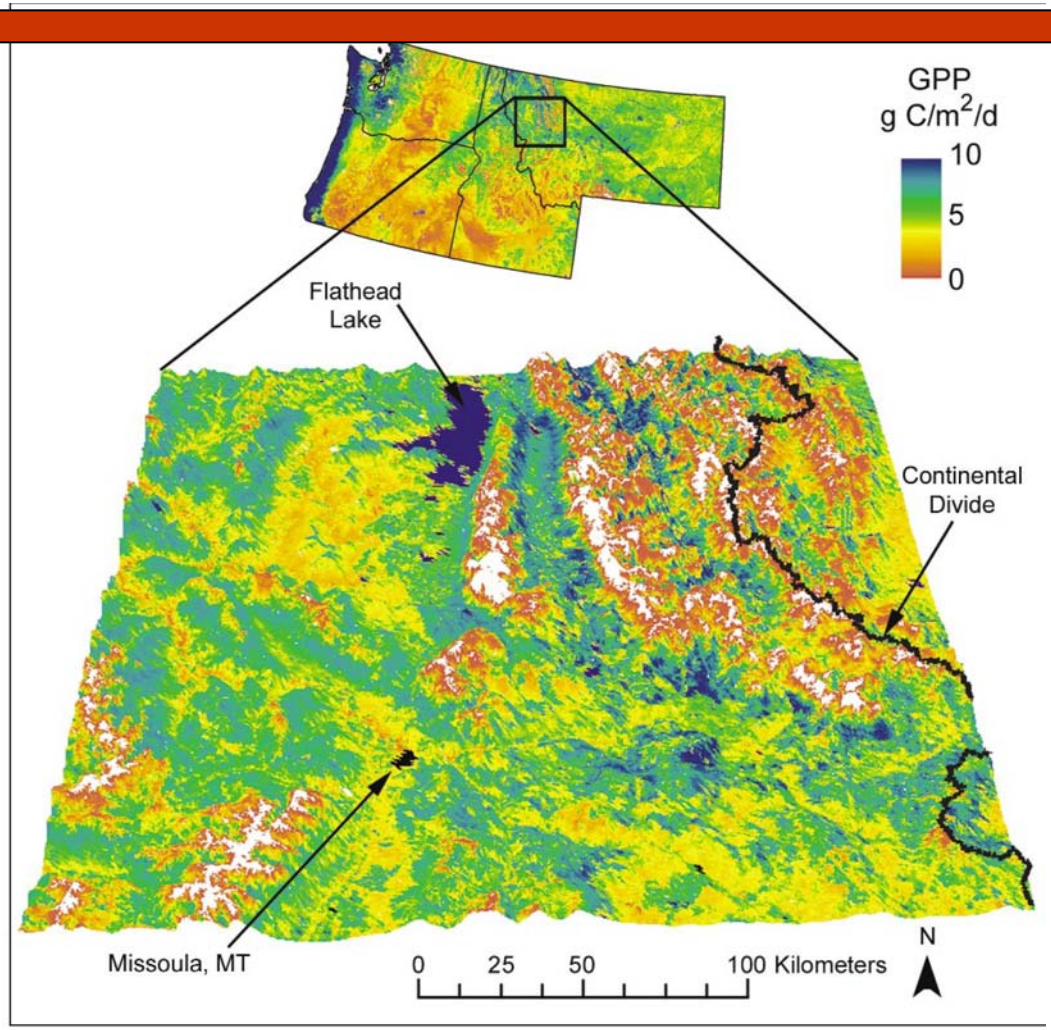
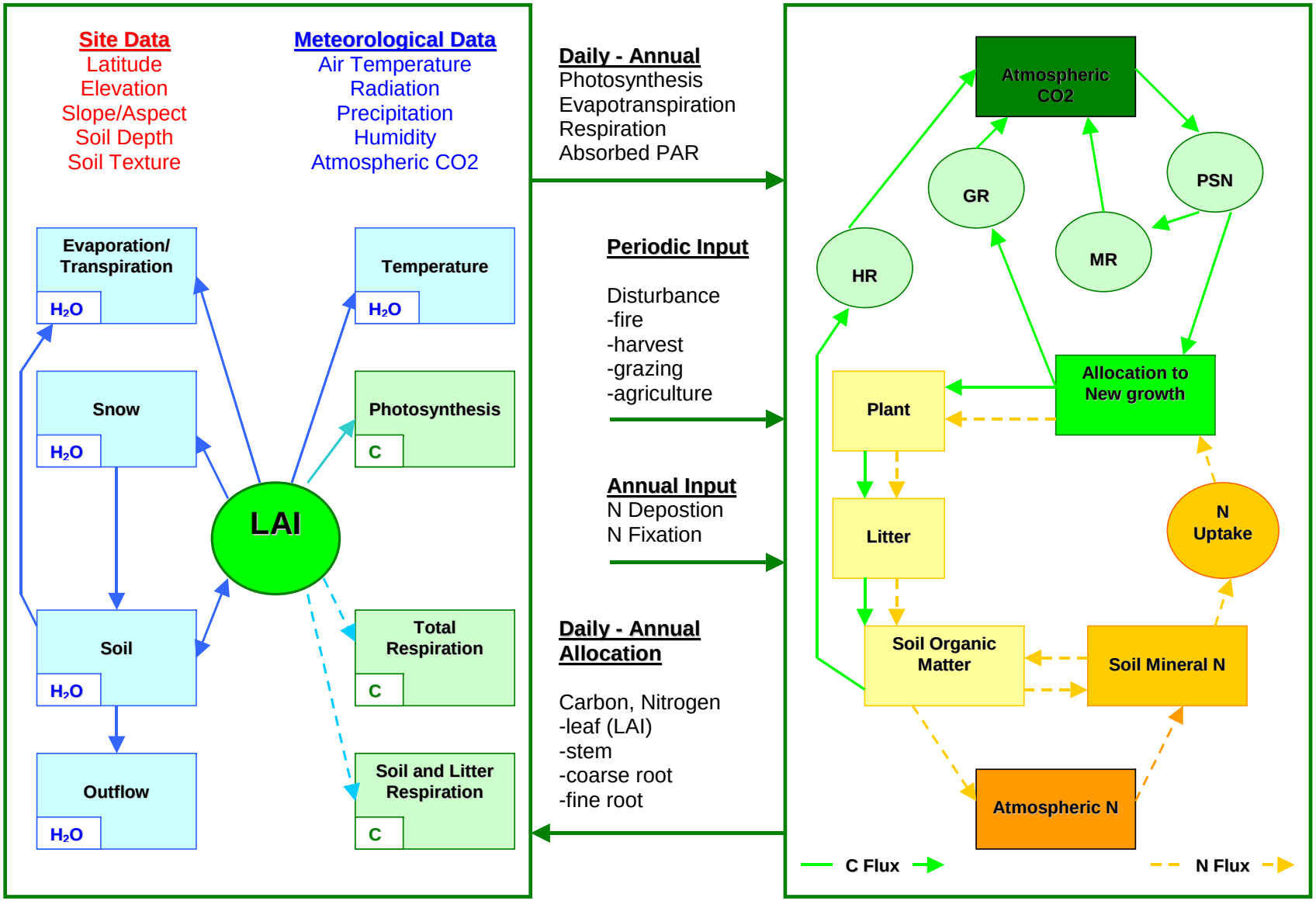


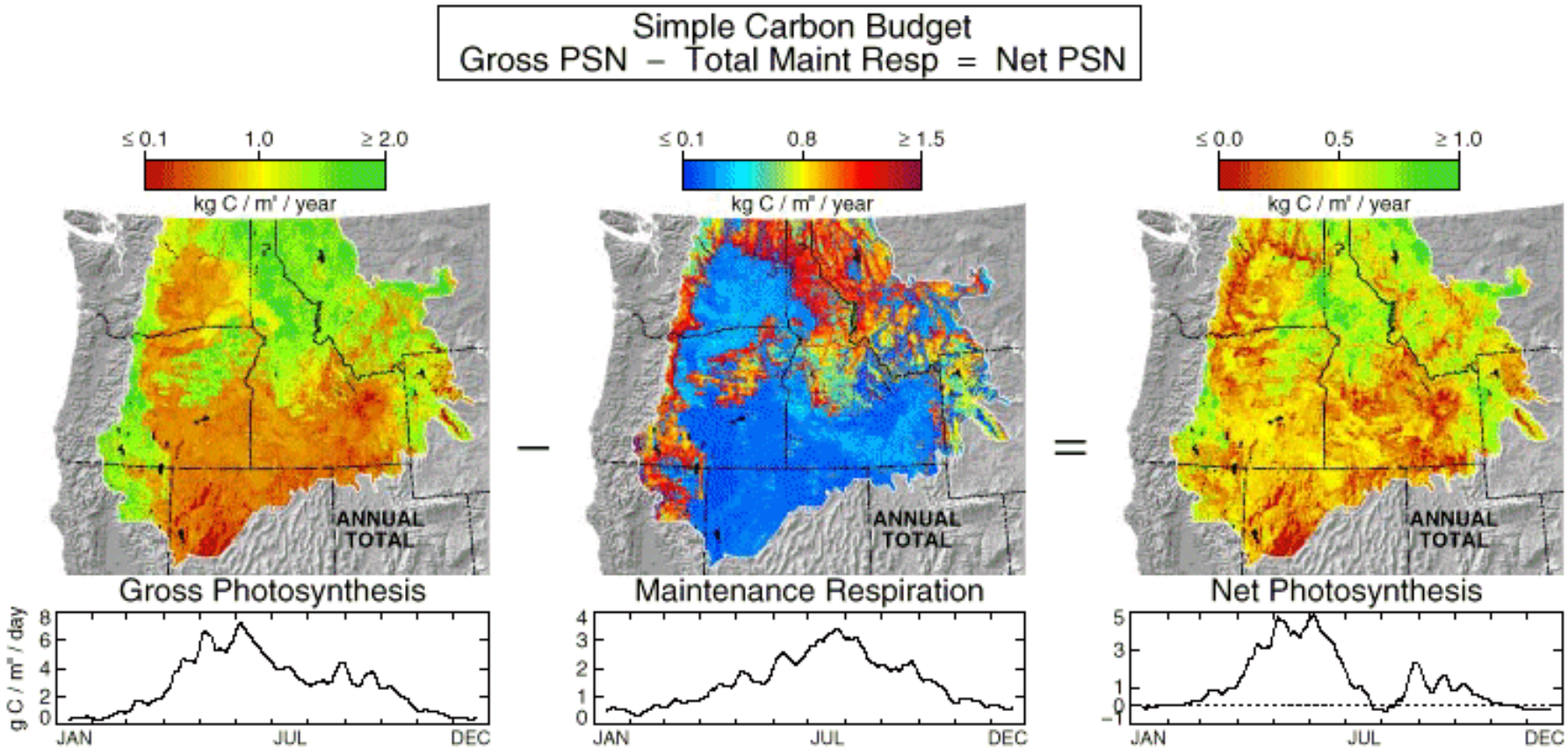

*Figure 10. Improvement in landscape resolution that the new 250-meter MODIS (Moderate Resolution Imaging Spectroradiometer) measurement of gross primary production (GPP) attains over the standard global MODIS GPP/NPP (net primary production) data set. The map shows GPP from western Montana for 2–10 June 2003, draped over digital elevation data.*

# Modeling ecosystem processes

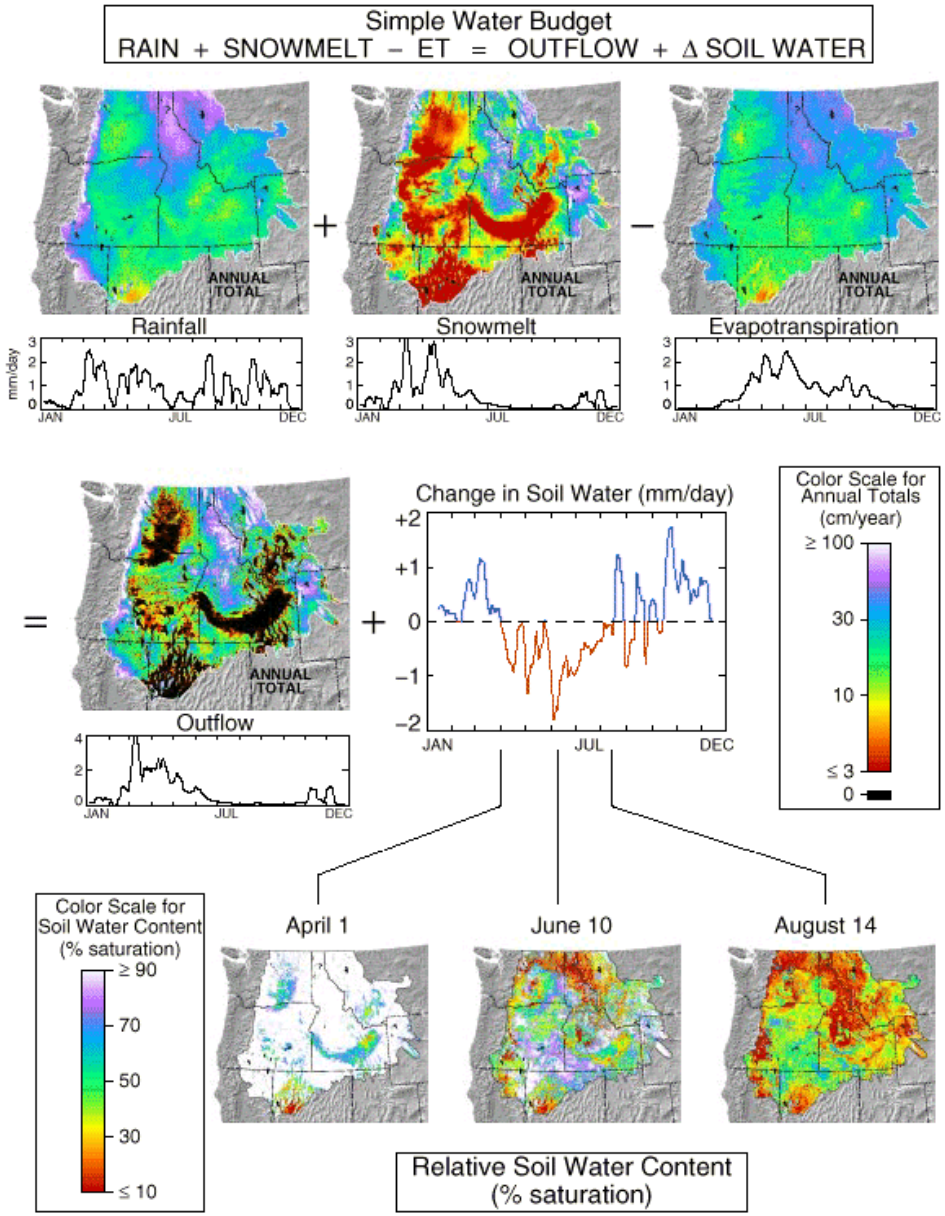
## BIOME - BGC



# An example of regional carbon budget estimation using TOPS



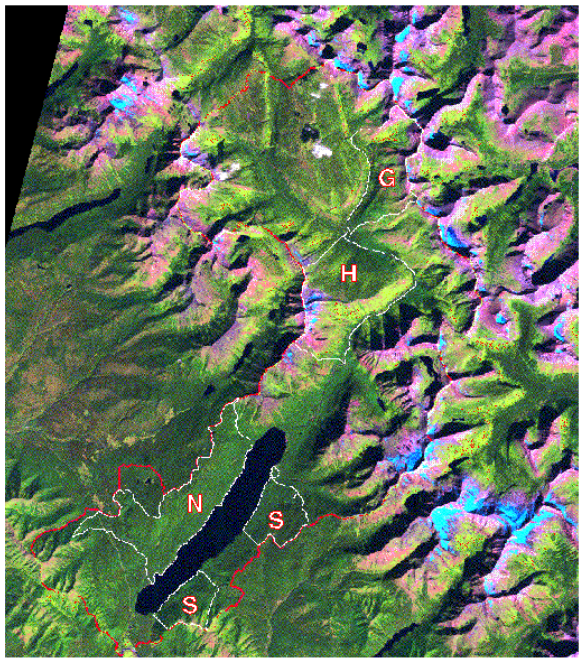
# An example of regional water budget estimation using TOPS



# Application of TOPS to the Lake McDonald watershed in the Glacier National Park, Montana

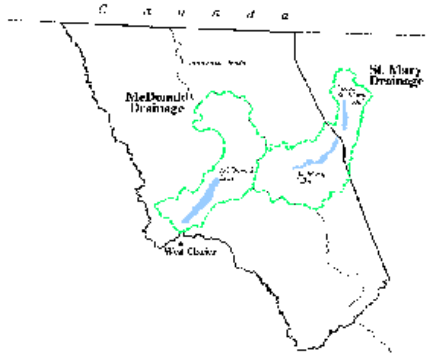
*Lake McDonald Watershed, Glacier National Park*

Landsat TM Data Bands 3,4,5 : Scene Date 9/3/90
Watershed size = 45,000 ha

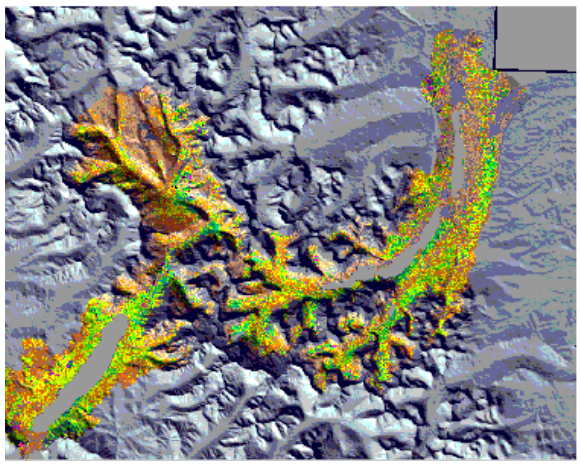



Watershed boundary delineated with red line. Sampled plot sites and compliment model areas delineated with white lines.

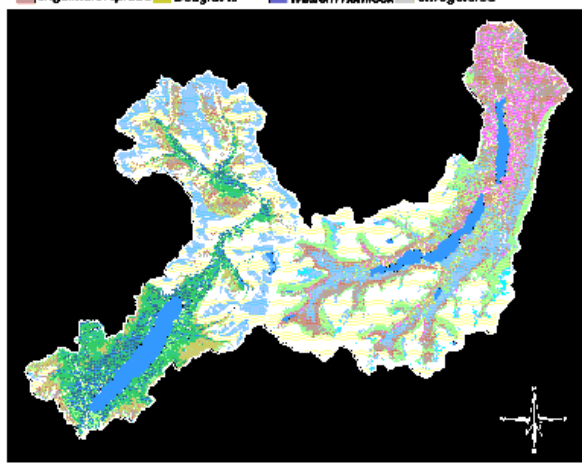
N = North Shore
S = South Shore
H = Heavens Peak
G = Granite Chalet



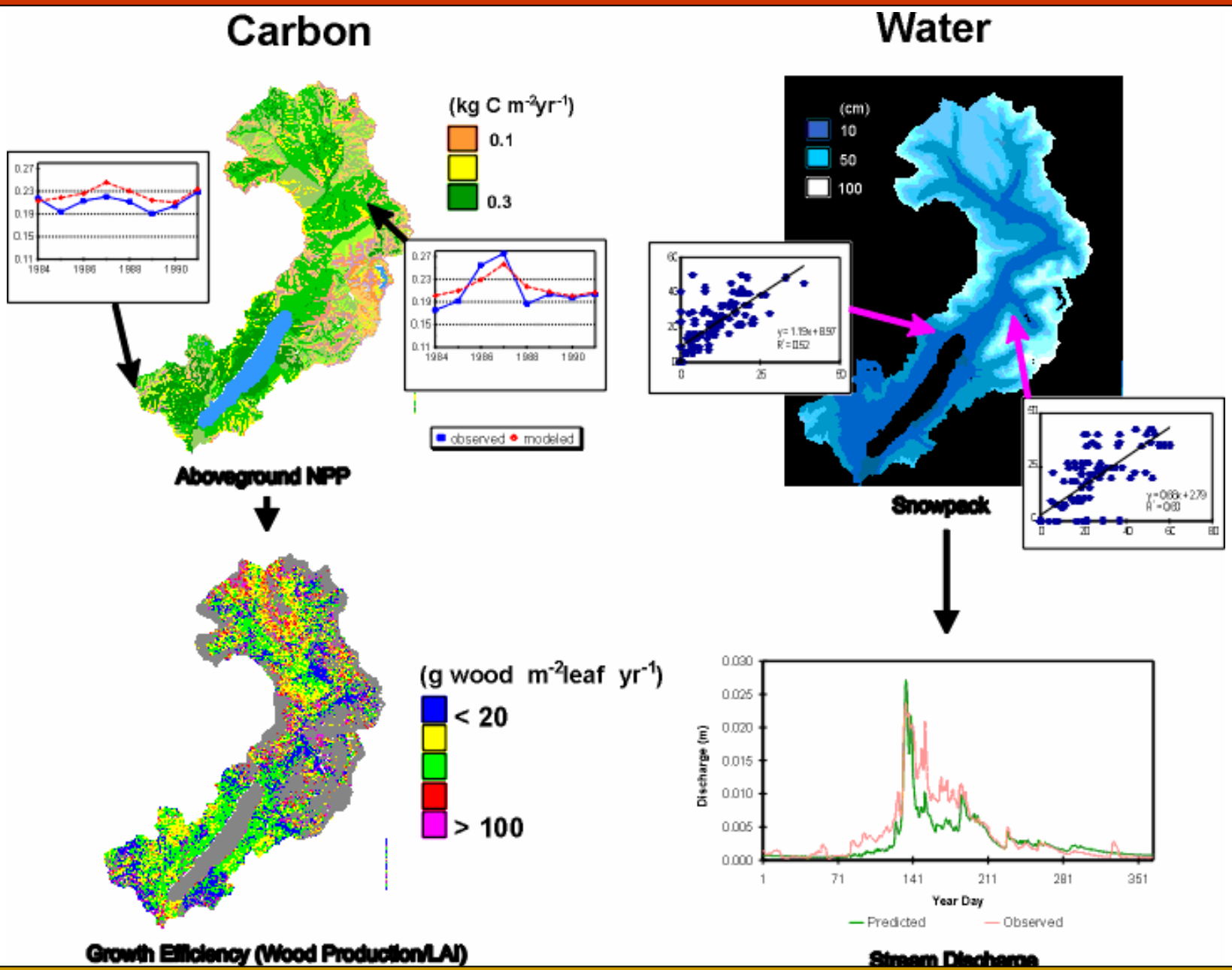

Leaf Area Index



Vegetation Types



# TOPS simulations of snowpack, streamflow and forest growth for Lake McDonald watershed



# Summary

**NPP is an integrated measure of ecosystem health and functioning**

**There is a long history of NPP observations**

**Routine monitoring of NPP from satellites is now possible**

**Advanced information systems allow on-demand, high resolution, and site-specific modeling and satellite data analysis**

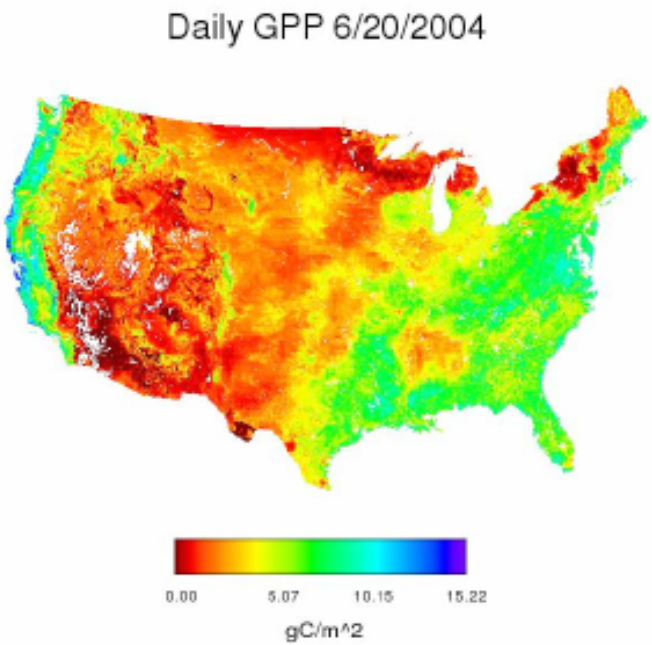
http://ecocast.arc.nasa.gov

# ECOLOGICAL FORECASTING

Monitoring, Modeling, and Forecasting the Impacts of Climate Variability and Change on Ecosystems



## Daily Ecocast




< previous | current > more images & data

## What is Ecocasting?

Ecological forecasting (or 'ecocasting') is the prediction of ecosystem parameters. NASA Ames is developing advanced computing technologies for converting massive streams of satellite remote sensing data into ecocasts that are easy to read and use.

NASA Ames, UWF IHMC, CMU, CSUMB, UMT, UW, and Fetch Technologies are collaborating to develop a distributed computing architecture for the production of ecocasts from satellite remote sensing data and other ancillary data sources. Applications of the Ecocast technology include fire forecasting, crop quality forecasting, snowpack and flood monitoring, and identification of anomalies in the carbon cycle and other biospheric processes.

## News

Daily updates of biospheric parameters are now available. See below for a selection of available parameters. Or download data and images here.

## Nowcasts & Forecasts

- Meteorology
- Hydrology
- Carbon Cycle